(12) UK Patent Application (19) GB (11) 2 158 570 A

(43) Application published 13 Nov 1985

(21) Application No 8507537

(22) Date of filing 22 Mar 1985

(30) Priority data

(31) 608760 (32) 10 May 1984 (33) US

(71) Applicant
Ex-Cell-O Corporation (USA-Michigan),
2855 Coolidge, roy, Michigan 48084, United States of America

(72) Inventors
Raymond J. Rulis,
Alvin D. Toelle,
John R. Farris,
Robert M. Halvorsen

(74) Agent and/or Address for Service
Withers & Rogers,
4 Dyers Buildings, Holborn, London EC1N 2JT

(51) INT CL[4]
F02C 9/26

(52) Domestic classification
F4T 101 1112 AH
B2F 143 316 KB
F1G 108
U1S 1987 B2F F1G F4T

(56) Documents cited
None

(58) Field of search
F4T
B2F
F1G

# (54) Mechanically operated fuel control system

(57) For controlling fuel flow to a plurality of spray bars 26 spaced circumferentially in the thrust augmentor section of a gas turbine engine, the system includes fuel staging valves 320 corresponding in number to the number of spray bars or spray bar bundles and spaced circumferentially around the outside of the augmentor casing, a synchronizing ring around the outside of the augmentor casing pivotally connected to each fuel staging valve and movable by a digital electronic controlled actuator to rotate a positive sealing, rotary valve member in each fuel staging valve relative to multiple spaced apart orifices therein and thereby control fuel flow to the spray bars. A plurality of air blast or dual orifice fuel nozzle assemblies spaced circumferentially around the combustor section of a gas turbine engine can be simultaneously controlled by similar means.

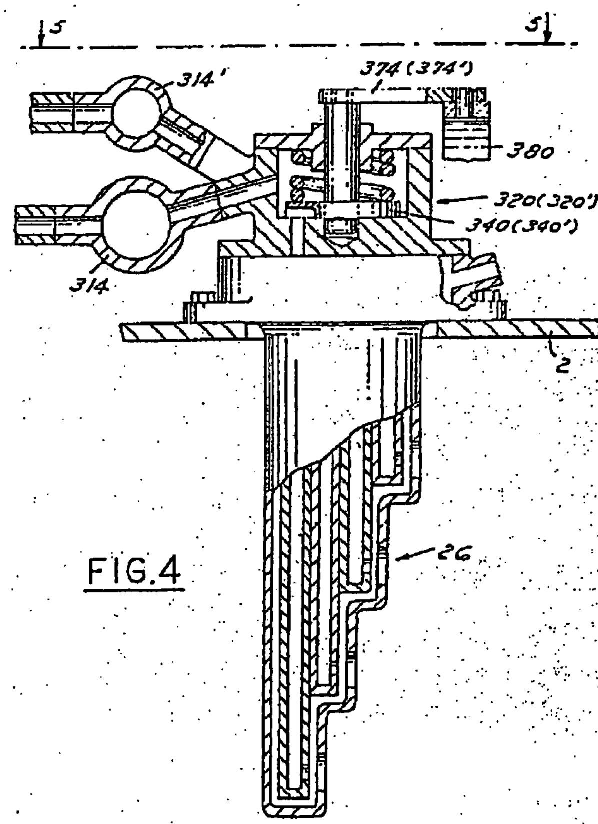



FIG.4

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

2158570

FIG.1

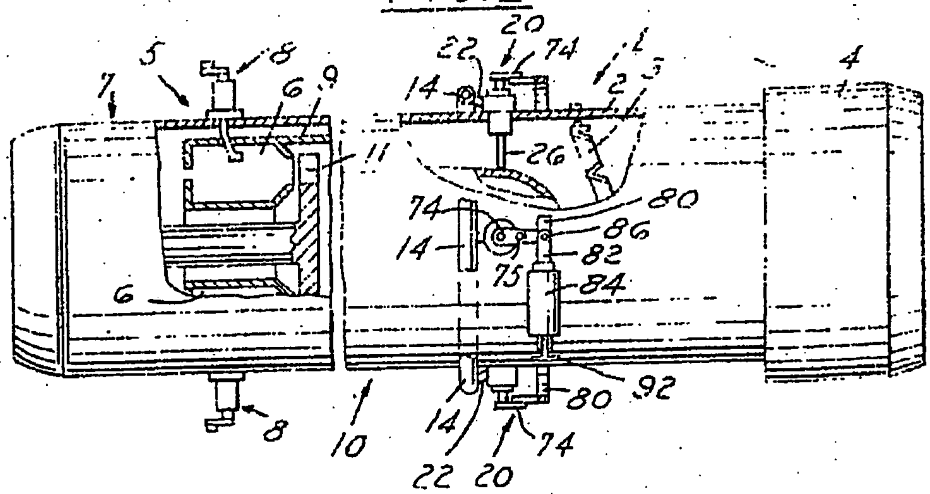
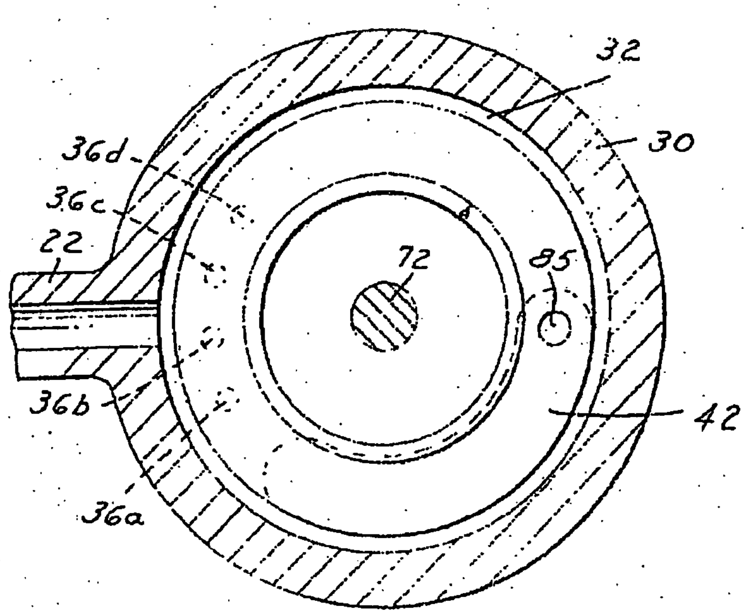



FIG.3



2158570

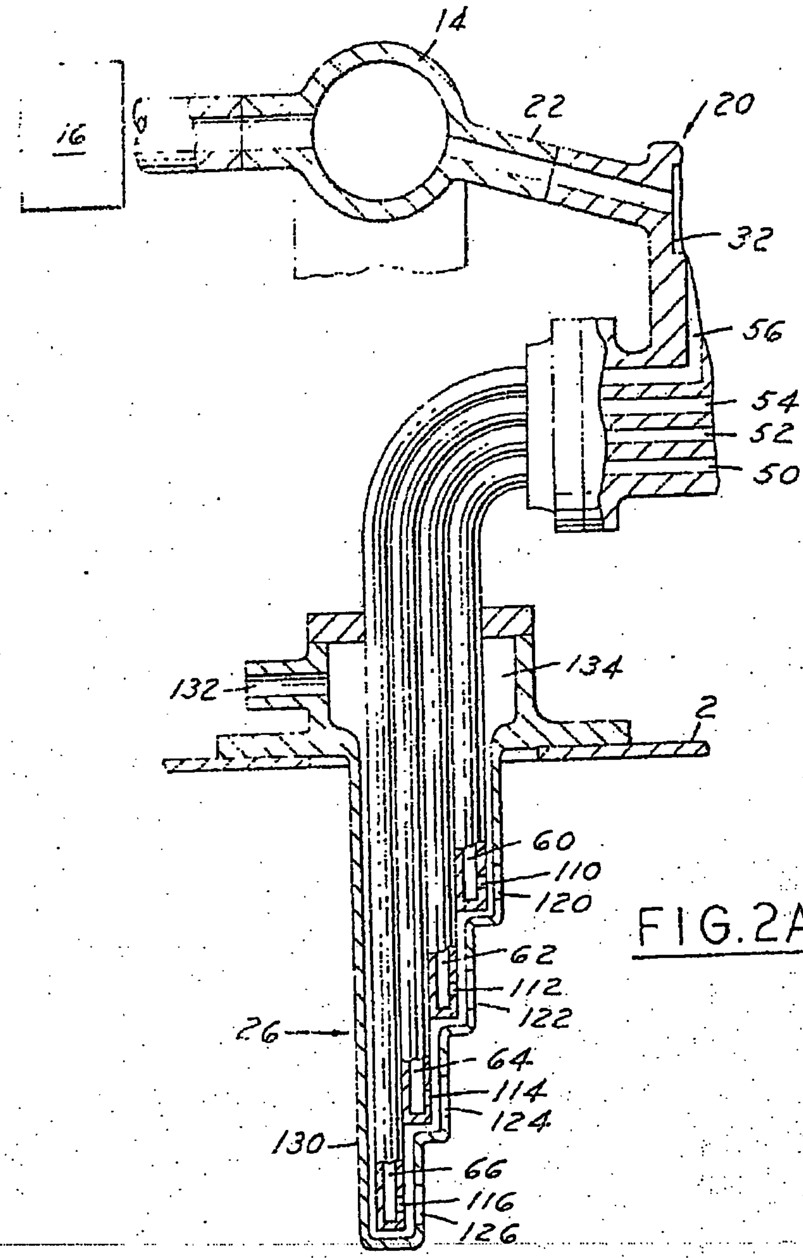



FIG.2A

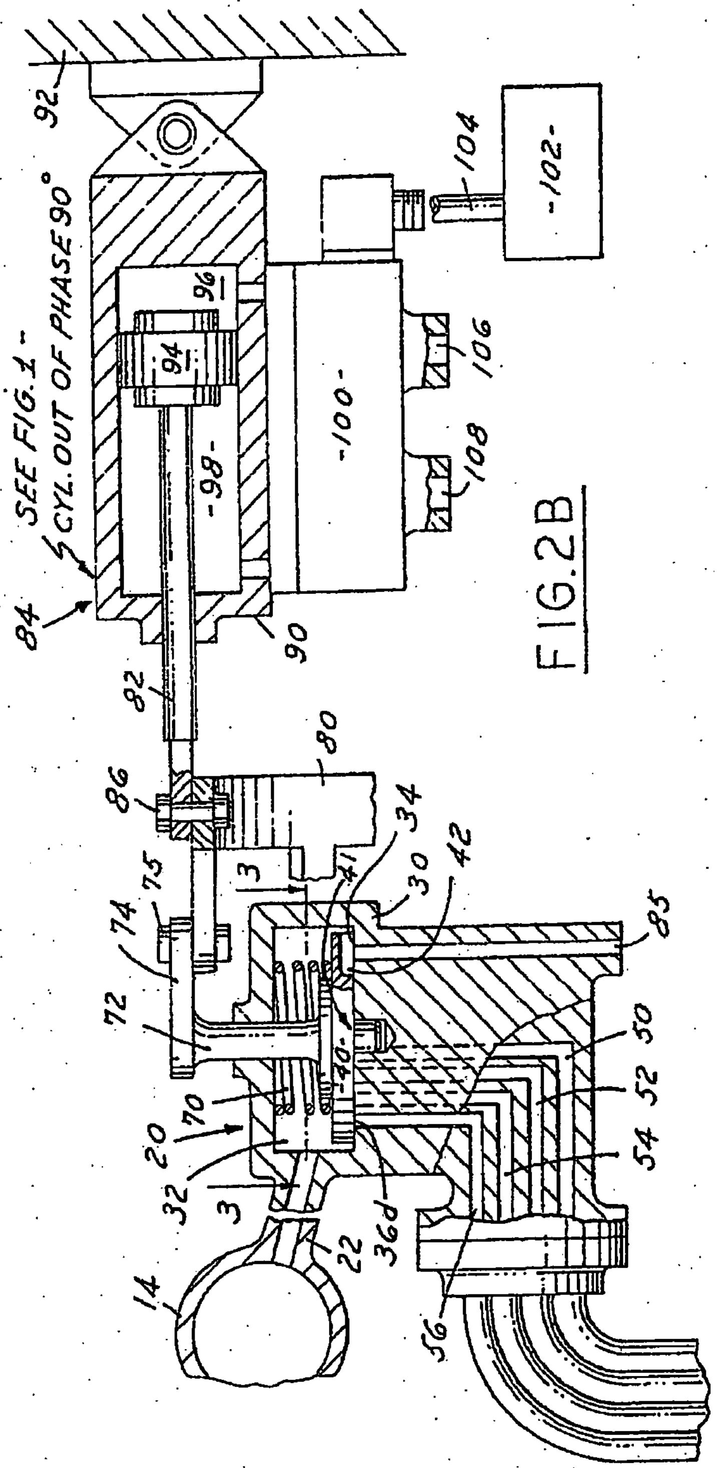

SEE FIG.1 -
CYL. OUT OF PHASE 90°
84
92
104
-102-
96
94
-98-
-100-
106
108
90
82
80
86
75
74
72
3
41
34
30
42
85
50
52
54
70
20
32
3
-40-
36d
22
14
56

FIG.2B

2158570

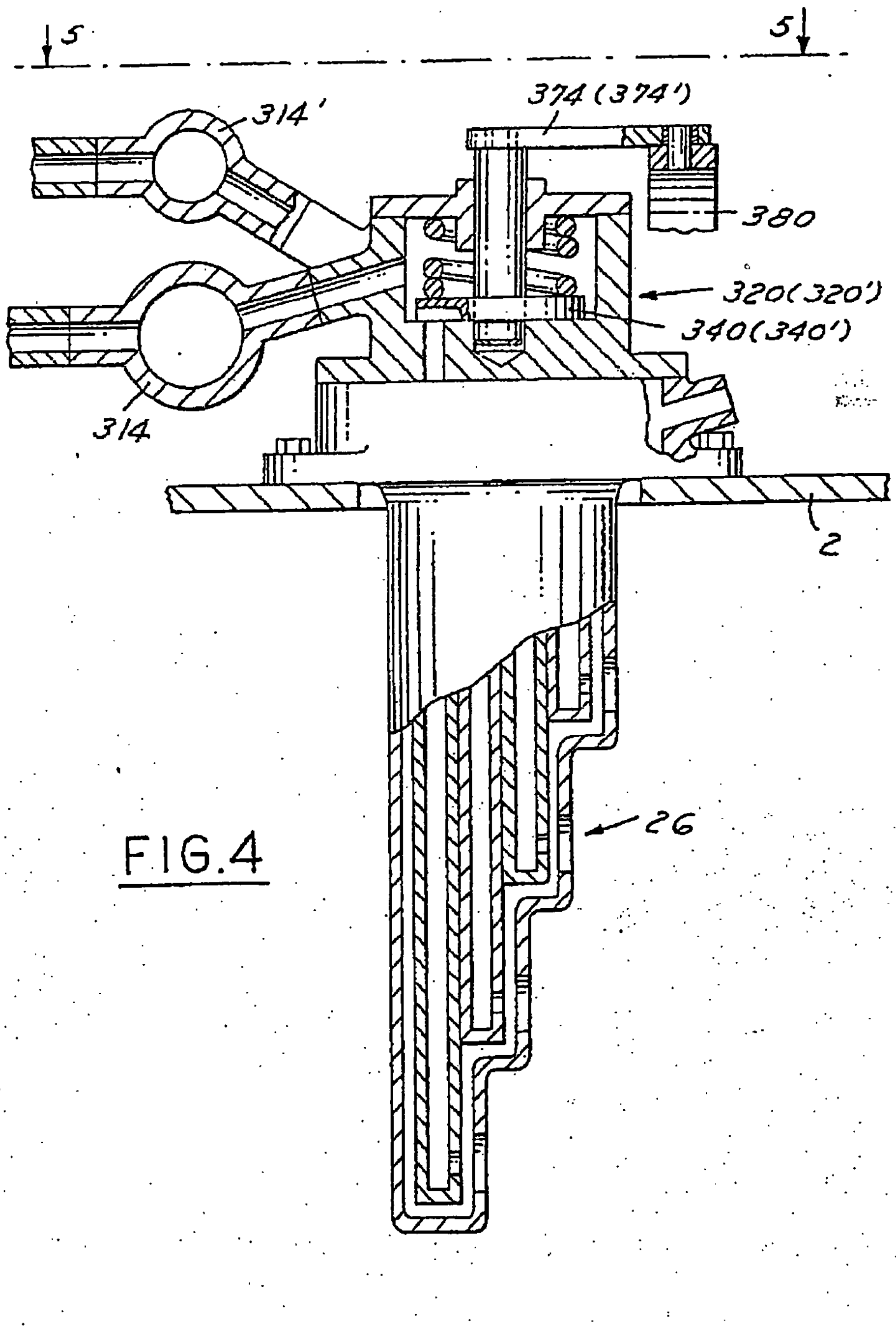



FIG.4

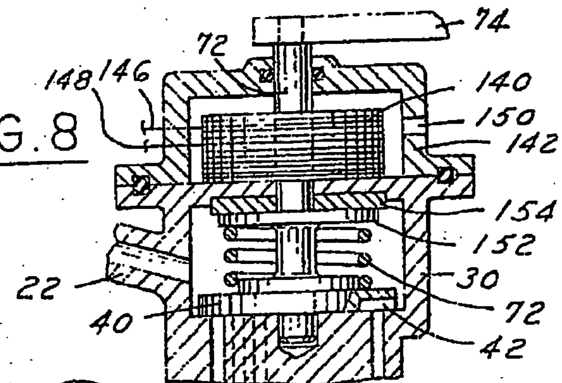

74
72
148
146
140
150
142
154
152
30
72
42
22
40

FIG. 8

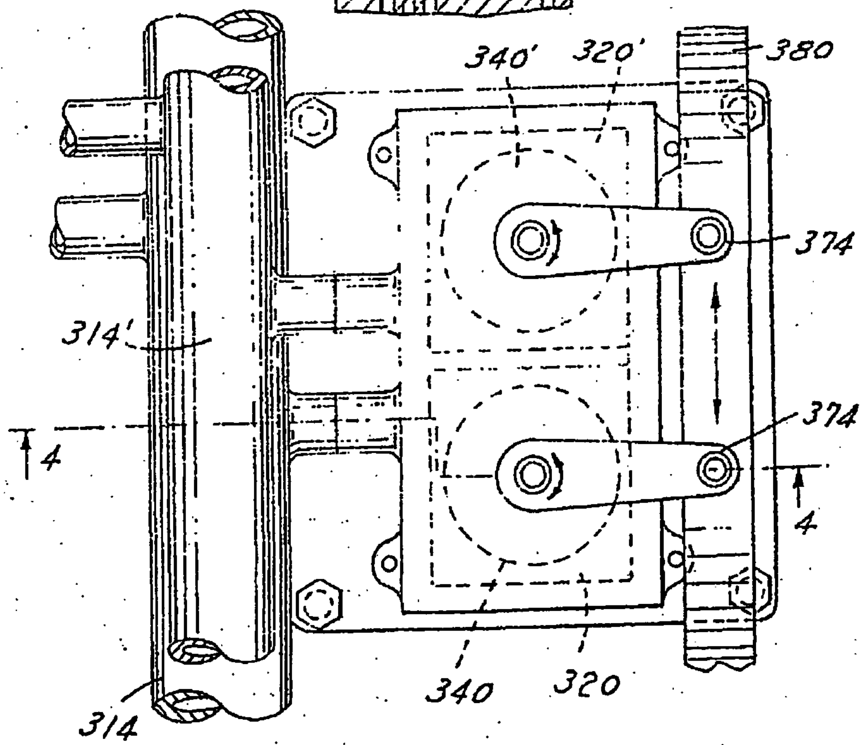

380
340'
320'
374'
314'
374
4
4
340
320
314

FIG. 5

2158570

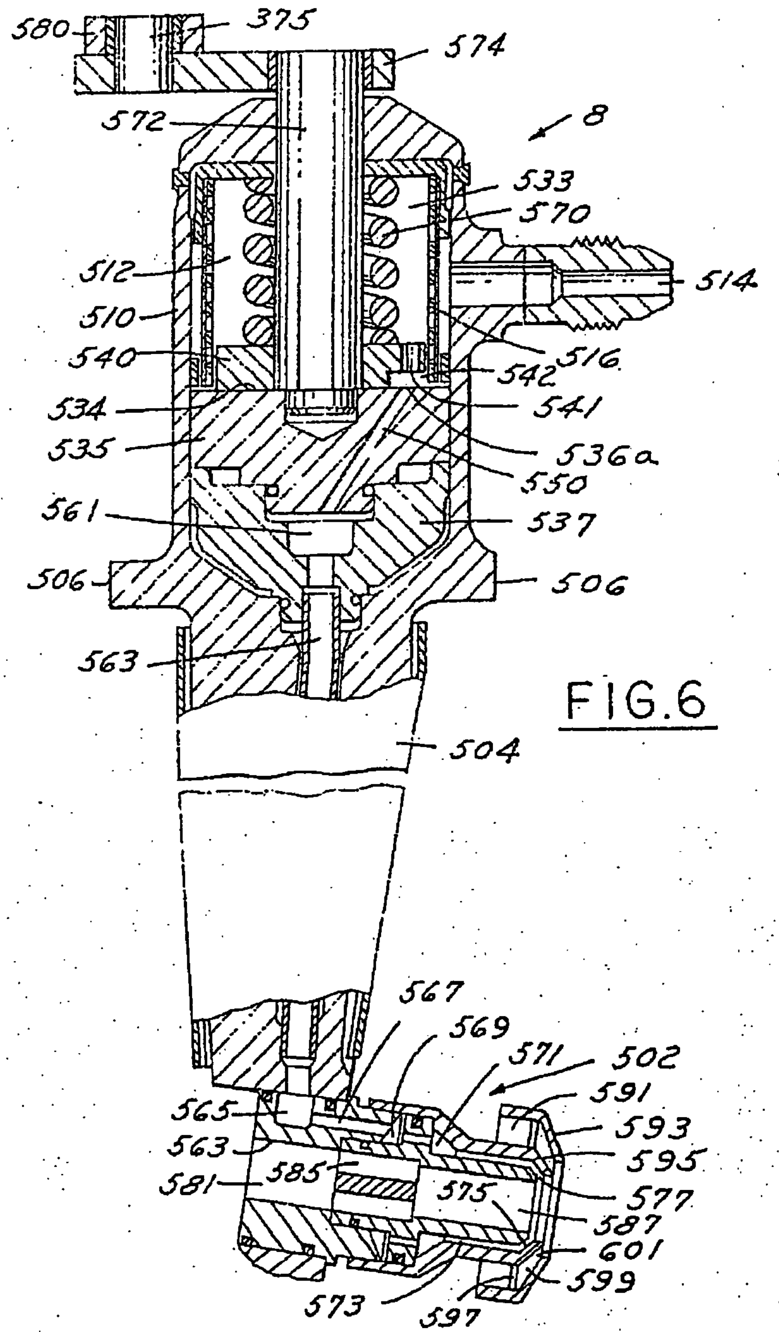



FIG.6

2158570

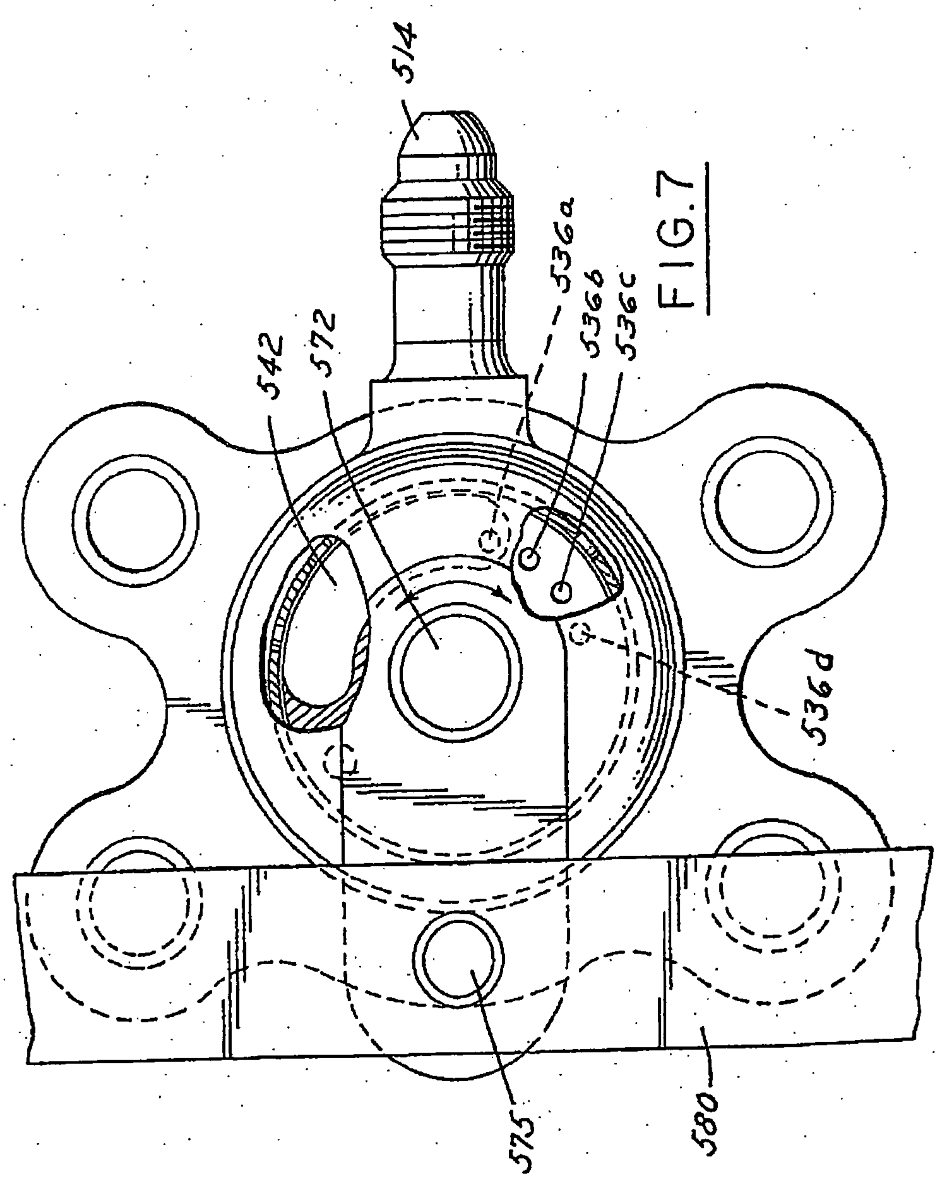



FIG.7

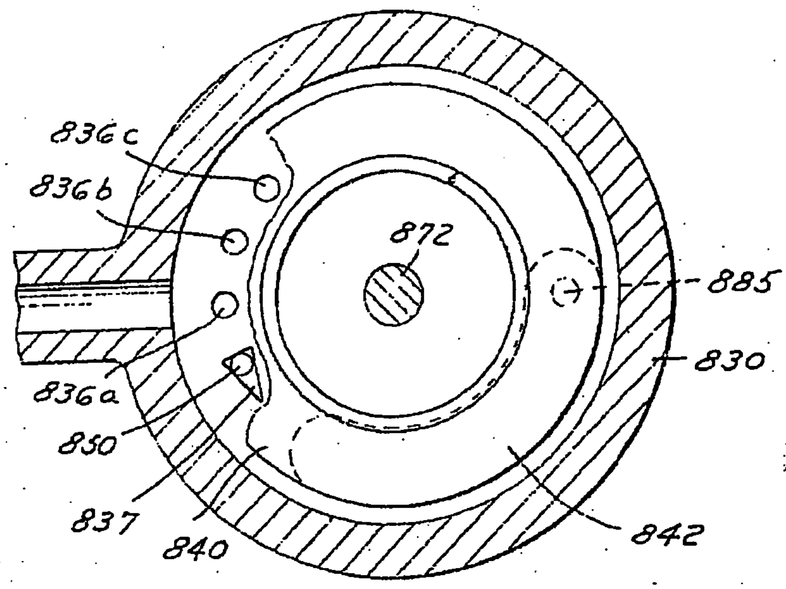

836c
836b
872
885
830
836a
850
837
840
842

FIG.9

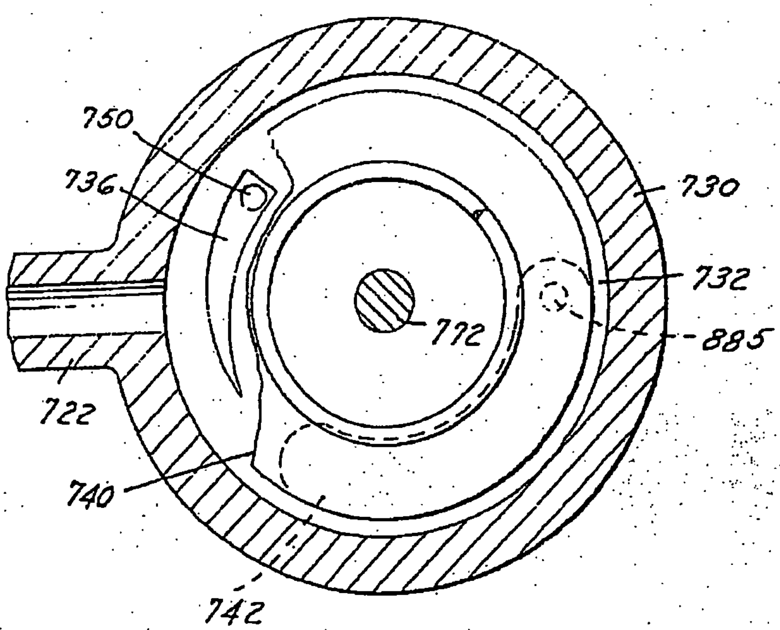

750
736
730
732
772
885
722
740
742

FIG.10

SPECIFICATION

**Mechanically operated fuel control system**

The present invention relates to fuel control valves more particularly, but not exclusively, such valves for controlling fuel injection into the thrust augmentor of afterburner and combustor of a gas turbine engine.

U.S. Patent 2,993,338 (H. D. Wilsted) discloses a fuel spray bar assembly which is supplied fuel from an annular fuel manifold extending around the outside of the engine casing and which radially extending tubular spray bars. Each tubular spray bar is closed at its inner end and a tubular valve sleeve is rotatable inside the tubular spray bar to bring a plurality of radially spaced apart orifices into various stages of registry to meter fuel flow into the afterburner section of a gas turbine engine. Each tubular valve sleeve is rotatably mounted by a bushing in a fuel collection manifold. Each bushing is connected to a lever which in turn is pivoted to an arm extending from a single operating or actuating ring extending exteriorly around the engine casing concentric with the fuel manifold. By rotation of the actuator ring, the fuel orifices of the rotatable valve sleeve can be brought into various stages of registry with orifices of the tubular spray bar to control fuel flow.

U.S. Patent 2,806,519 (K. A. Basford et al) discloses a fuel control system for an internal combustion engine with means to compensate for an engine operating variable. The system includes a piston/cylinder actuator which varies the extent of eccentric rotation of a spring biased plate valve relative to multiple fuel passages.

U.S. Patent 4,312,185 (Dudley O. Wash et al) describes a low profile fuel injection system for a thrust augmentor of a gas turbine engine.

U.S. Patent 3,949,775 (Richard H. Cornell) illustrates a fuel supply system for a gas turbine engine wherein a plurality of flow dividing valves disposed about a manifold are positively controlled by an actuator which interconnects the flow dividing valves by linkage means.

Other fuel spray systems for the afterburner or thrust augmentor section of gas turbine engines are described in U.S. Patent 4,315,401; U.S. Patent 3,908,363; U.S. Patent 3,793,838; U.S. Patent 3,719,402; U.S. Patent 3,698,186 and U.S. Patent 3,147,594. U.S Patent 4,337,616 and U.S. Patent 2,928,241 illustrate fuel control systems as well.

The present invention contemplates a mechanically operated fuel staging and distribution system for controlling fuel flow to a plurality of fuel injection devices in a combustor of a gas turbine engine or other internal combustion engine. The staging and distribution system includes in a typical working embodiment a fuel supply means and a plurality of fuel injection devices with discharge orifices inside the combustor and to which fuel flow is controlled by multiple fuel staging valve means spaced circumferentially around the outside of the combustor and operatively positioned between the fuel supply means and each fuel injection device. Each fuel stating valve means includes a positive sealing, rotary valve member and multiple sequential orifices relative to which the valve member is rotated to control fuel flow to the associated fuel injection device. The valve members are operated in unison outside the combustor by synchronizing means operatively connected to each valve member to rotate same relative the sequential orifices. The synchronizing means is in turn actuated by suitable means, preferably a digital or analog electronically controlled actuator using closed or open loop control.

The present invention also contemplates a mechanically operated fuel metering system for metering fuel flow to a plurality of fuel injection devices in a combustor and to which fuel is metered by multiple fuel metering valve means having a variable orifice and positive sealing, rotary valve member. The rotary valve members are operated in unison outside the combustor by synchronizing means connected to each valve member.

The combustor for which the fuel control system of the invention is especially useful is the thrust augmentor or afterburner of a gas turbine engine or the upstream combustion chamber(s) thereof.

The valve means of either system may be operatively associated with each of a plurality of elongated spray bars or bundles of spray bars extending radially into the thrust augmentor or afterburner of a gas turbine engine to distribute fuel to different locations therein or each of a plurality of concentric spray rings in the augmentor or afterburner for the same purpose. In another preferred embodiment, the fuel staging or metering valve means may be incorporated into each of a plurality of fuel injection nozzle assemblies of the known air blast or dual orifice types supplying fuel to the combustor section of a gas turbine engine or to a selected group of such nozzle assemblies such as those adjacent the igniter in the combustor.

The mechanically operated fuel staging and distribution system of the invention offers improve system response, performance, fuel distribution and metering accuracy and may be controlled by digital or analog electronic control means either closed or open loop. In addition, since the system does not use fuel pressure itself to actuate the valve means, there is no substantial fuel pressure drop associated with the valve means and as a result there is higher available pressure at the discharge orifices for atomisation of fuel.

Embodiments of the present invention will now be described by way of example with reference to the accompanying drawings in which:

*Figure 1* is a diagrammatic illustration of portions of a gas turbine engine;

*Figure 2A* is a partial sectional view of the fuel staging and distri- bution system for a multi-zone spray bar thrust augmentor system of a gas turbine engine;

*Figure 2B* is a partial sectional view which, when viewed together with Figure 2A, shows an individual multi-zone spray bar of the system of Figure 1, and its operative connection to the fuel staging

valve thereof;

*Figure 3* is an elevation of the fuel staging and distribution valve of the system;

*Figure 4* is a part-sectional view of a system for controlling injection of fuel into the fan and core section of a gas turbine engine;

*Figure 5* is an elevation of the fuel staging and distribution valve for the system of Figure 4;

*Figure 6* is a part-sectional view of an air blast fuel nozzle assembly with the fuel staging and distribution valve incorporated therein;

*Figure 7* is a plan view of the valve of Figure 6;

*Figure 8* is a part-sectional view of a fuel staging and distribution valve assembly having a sensor to sense valve position;

*Figure 9* is a plan view of the metering valve of the system; and

*Figure 10* is a plan of the combined staging and metering valve of the system.

Although the mechanically operated fuel staging and distribution system and metering system of the invention are illustrated herebelow with respect to fuel control for a gas turbine engine, they are not so limited and have applicability to other internal combustion engines as well.

Figures 1 to 3 illustrates a digital or analog electronically controlled mechanically operated augmentor multi-zone staging and fuel distribution system for a gas turbine engine having a thrust augmentor section 1 defined by outer casing 2 having flame holder 3 and having an exhaust nozzle 4 receiving gas flow from augmentor section 1. Upstream of the augmentor section is the combustor section 5 having combustors 6 disposedc circum- ferentially inside inner casing 6. As is well known, the combustors 6 received compressor discharge air A from the upstream combustors 6 from fuel nozzle assemblies 8 and burned with the air for discharge into turbine section 10 having turbine blades 11. Compressor discharge air also flows between inner casing 9 and outer casing 2 as is well known.

The fuel control system of the invention is applicable for controlling fuel flow to the fuel nozzle assemblies 8 in the combustor section and to the spray bars 26 in the augmentor section. In Figs. 1-3, the fuel control system is illustrated for controlling fuel flow to the spray bars of the augmentor section.

In these figures the system includes an annular fuel manifold 14 which extends generally concentrically around outer casing 2. Fuel is supplied to the fuel manifold by a standard metering valve 16 which may be under digital or analog electronic control by control device of known type. The fuel manifold is connected to a plurality of fuel staging and distri- bution valves 20 by conduits 22. It will be understood that a plurality of such valves are spaced circumferentially around the outer casing 2 to control flow to a plurality of radially extending fuel spray bar bundles 26 supported inside the augmentor section 10 from the casing 2 for distribution of fuel to different zones in the augmentor or section, Fig. 2A.

Each fuel staging and distribution valve 20 includes a valve body 30 having an interior chamber 32 in fuel flow relation with conduit 22 and having a flow control surface 34 with a plurality (four shown) of sequential outlet orifices or apertures 36a-d therein for staging fuel flow. Disposed on the flow control surface 34 is a positive sealing fuel staging valve disk 40 which is rotatable relative to the orifices 36 as shown by the arrow in Fig. 3. The valve disk 40 includes a circumferential shut-off and staging groove 42 on the disk surface facing and mating with the flow control surface 34 and which is substantially parallel therewith. As is apparent, rotation of the valve disk 40 in the clockwise direction in Fig. 3 will sequentially expose more orifices 36 to the fuel in chamber 32 and admit fuel thereto for flowing through passages 50, 52, 54, 56 in fuel flow communication with passages 60, 62, 64, 66 of the spray bar and constituting the four zones thereof as will be explained herebelow.

The valve disk 40 will shut off fuel flow to the metering orifices 36 when rotated in the counterclockwise direction (Fig. 3) a sufficient extent to cover or seal all the multiple sequential orifices 36 against fuel flow from chamber 32. The mating facing sealing surfaces 34, 41 of the flow control surface and valve disk, respectively, are machined to provide positive sealing therebetween while the valve disk is biased against the flow control surface by a coil spring 70. By positive sealing is meant that the surfaces 34, 41, are in intimate contact with no substantial clearance therebetween so that there is substantially no fuel leakeage therebetween. The spring 70 is disposed between the upper inner wall of chamber 32 and the side of the valve disk facing away from disk side 41 and encircles a shaft 72 extending from the valve disk 40 through the upper inner wall of chamber 32 to the exterior. The shaft 72 terminates in a longitudinally extending arm 74 which is pivotally connected by pivot pin 75 to linkage and synchronizing ring 80 which extends around the circumference of outer casing 12 generally concentric with fuel manifold 14 as shown in Fig. 1. The ring 80 in turn is pivotally connected at one point to shaft 82 of hydraulic actuator 84 by pivot pin 86. As shown in Fig. 1, shaft 82 is connected to ring 80 to exert a tangential type force thereon to rotate the ring in one direction or the other. Or, a bellcrank linkage may be employed if the actuator 84 is disposed parallel to the axis of ring 80 (Fig. 2B) where the actuator is shown out of position for convenience.

A passage 85 may be provided in the valve body 30 in communication with fuel chamber 32 at one end and connected in fuel flow to the fuel manifold 14 by suitable conduit means (not shown) at the other end to provide recirculation of fuel flow back to the fuel tank (not shown) for maintaining acceptable manifold fuel temperature when the valve disk 40 has closed off all the sequential orifices 36. The passage 85 would be closed off by valve disk 40 during fuel flow but opened when sequential orifices 36 are closed off.

The actuator 84 includes a housing 90 pivotally attached to a suitable support 92 so that housing

90 can pivot, if necessary, during motion of ring 80. Support 92 may be attached to the outer casing 2. Shaft 82 is connected to piston 94 for sliding movement therewith as determined by hydraulic pressure in chambers 96, 98 in the housing 90. Hydraulic pressure in chambers 96, 98 can be varied by a spool type direct drive servovalve 100 under digital or analog electronic control of control device 102 connected electrically thereto through leads 104. The control device 102 may comprise known digital or analog control device. The servovalve 100 receives hydraulic fluid via return and supply connections or fittings 106, 108, respectively, in communication with a suitable source (not shown) of hydraulic pressure in known fashion. One or more of such actuators 84 may be provided at different locations on the synchronizing ring 80. The actuator 84 causes ring 80 to rotate in one direction or the other through pivot 86 and this in turn will cause shaft 72 of the valve disk 40 to be rotated in one direction or the other through pivot 75. The valve disks 40 of each staging and distribution valve 20 thus can be caused to rotate relative to multiple, sequential orifices 36 and stage fuel flow from chamber 32 thereto in controlled fashion under digital or analog electronic control. Of course, the actuator 84 can be hydraulic, pneumatic, electromechanical, mechanical or other known types.

The fuel metered into the metering orifices will flow through passages 50, 52, 54, 56 in the valve housing into passages 60, 62, 64, 66 in the bundle of spray bars 26 which distribute fuel to different zones in the augmentor section. As shown, passages 60, 62, 64, 66 terminate at successively greater distances from the outer casing 12 to define four spray zones for fuel distribution in the augmentor section. Each passage includes an open fuel discharge orifice 110, 112, 114, 116 sized to maintain maximum zone fuel flow at maximum pressure drop thereacross.

Opposite each discharge orifice 110, 112, 114, 116 is an air sealing/ atomizing discharge orifice 120, 122, 124, 126 for maintaining fuel distri- bution and atomization at low fuel flows. Orifices 120, 122, 124, 126 are formed in an envelope or housing 130 supported on the outer casing 2 as shown and receiving compresor bleed air through passage 132. Air flows through passage 132 into chamber 134 and then through the envelope out orifices 120, 122, 124, 126 for the purpose described.

By means of the system described hereinabove, fuel flow can be accurately staged and distributed to each of the four zones of each spray bar 26 under digital or analog electronic control. The digital or analog control device 102 may be used in an open loop or closed loop system. The closed loop system can include a suitable position or other feedback sensor in the actuator 84, operatively associated with synchronizing ring 80 or linkage components or on the fuel valve means itself. For example, Fig. 8 shows a position feedback sensor 140 disposed around shaft 72 of the fuel staging and distribution valve. The sensor is housed in an auxiliary housing 142 bolted onto valve body 30. Leads 146, 148 from the sensor 140 extend to control device 102 to provide position feedback signals. The auxiliary housing 142 includes an overboard drain 150 for discharge of unwanted fuel therefrom. Fig. 8 also shows the shaft 72 including an annular shoulder 152 which rotates against a carbon or other suitable sealing member 154.

Of course, a single spray bar may be provided having only one passage corresponding to one of passages 60, 62, 64, 66 to receive fuel from the valve 20 which would function as a fuel staging valve and such a passage would be provided with mulltiple discharge orifices corresponding to orifices 110, 112, 114, 116 spaced apart along its length to distribute fuel to different zones within the augmentor section. Fuel flow through the single spray bar passage would be successively increased in stages or increments as individual orifices in the flow control surface of the valve 20 are exposed by valve disk rotation and thus fuel flow through the space- apart discharge orifices along the spray bar would be uniformly increased.

Figs.4 and 5 illustrate a similar system for separate control of fuel flows to spray bars disposed in different radial locations in a thrust augmentor such as in an outer fan duct (not shown) and inner core duct (not shown) of known construction; e.g., see U.S. Patent 4,312,185, from a common synchronizing ring 380 actuated by a common actuator (not shown) like that described with respect to Figs. 1-3. In this arrangement, dual fuel staging valves 320 and 320′ are provided and receive fuel from separate manifolds 314 and 314′ extending around the augmentor casing 312. Each valve 320, 320′ would have an arm 374, 374′ pivotally connected to the ring 380 for simultaneous rotation of the associated valve disks 340, 340′ by movement of the ring 380. In this way, fuel flow to spray bars in different locations can be independently controlled by the common ring 380 under digital or analog electronic control of a common control device.

Figs. 6-7 show another embodiment of the invention wherein a fuel staging system is incorporated into an air blast fuel nozzle assembly 8 (Fig. 1) which includes an air blast nozzle 502 supported on a strut 504 having flanges 506 for attachment to engine casing 2 surrounding the combustor section 5 of the engine. A plurality of these fuel nozzle assemblies would be mounted around the engine casing as shown in Fig. 1.

The strut includes a housing 510 with a chamber 512. Chamber 512 receives fuel from fitting 514 connected to a fuel manifold (not shown) like the fuel manifold shown in Figs. 1-4. A filter sleeve 516 is disposed in the chamber 512 and fuel flows therethrough into an interior chamber 533 above a valve disk 540 having an aperture 541 connecting circumferential shut-off and staging groove 542 with chamber 533. As in the above embodiments, valve disk 540 is rotatable relative to multiple sequential orifices 536 a-d shown in Fig. 7 in a flow control surface 534 of stationary insert 535 which

is supported on another insert 537 brazed in the housing and exposes the orifices successively to fuel in chamber 533. The valve disk 540 is rotatable by shaft 572 having arm 574 pivotally connected by pivot pin 575 to synchronizing ring 580. Ring 580 in turn is actuated in the same manner as described above for Figs. 1-3. Positive sealing between valve disk 540 and flow control surface 534 is achieved as described above for Figs. 1-3 by proper machining of the mating surfaces and biasing by spring 570.

Fuel flow through multiple passages (only 550 shown) from orifices 536 into a common chamber 561 can thereby be staged in increments. From chamber 561, fuel flows through passage 563 in strut 504 and into annular chamber 565 in the air blast nozzle. From chamber 565, fuel flows through passage 567 into annular chamber 569 and then through multiple swirler slots 571. From swirler slots 571, the fuel flows into annular chambers 573, 575 and is discharged out annular downstream discharge orifice 577.

At the same time, compressor discharge air enters upstream into central air passage 581 in inner sleeve 563, passes swirler vanes 585 and exits from orifice 587 inside the fuel cone exiting from discharge orifice 577. Also, other compressor air enters chamber 591 between the outer shroud 593 and intermediate sleeve 595 and flows through annular chambers 597, 599 for discharge out discharge orifice 601 from the exterior of the fuel spray cone exiting discharge orifice 577.

Air blast fuel nozzles of the type shown in Fig. 6 are described in more detail in U.S. Patent 3,684,186 issued to Helmrich. Of course, the fuel staging and distribution system shown in Fig. 6 could be incorporated into well know dual orifice or other fuel nozzle assemblies as well.

In the embodiments of the invention for metering fuel to multiple spray bars in the augmentor section 10 or to multiple fuel nozzle assemblies in the combustion section 5 of the a gas turbine engine, the multiple, sequential orifices 36a-d shown in Fig. 3 would be replaced by a variable area orifice 736, as shown in Fig. 9, relative to which the positive sealing, rotary valve disk 740 with circumferential groove 742 is rotated to vary the area of the orifice 736 exposed to fuel in fuel chamber 732 in valve body 730. For example, valve disk 740 is rotated clockwise in Fig. 9 to gradually increase the area of orifice 736 and increase fuel flow. Of course, rotation of the valve disk 740 would be effected by synchronizing ring 780 through arm 774 as described hereinabove relative to Figs. 1-3. The other components of the fuel control system would be the same as those described above for Figs. 1-3.

Fig. 10 shows another embodiment of the invention for both metering and staging fuel flow to either multiple spray bars in the augmentor section 10 or fuel nozzle assemblies in the combustion section 5. As is apparent, a variable area metering orifice 837 is included in sequence ahead of the multiple, sequential orifices 836a-c so that as the valve disk 840 is rotated clockwise, the area of the metering orifice 837 is intially increased to meter fuel flow and then with further rotation the orifices 836a-d are successively exposed to stage fuel flow. This sequential arrangement of a metering orifice 837 and multiple, sequential staging orifices 836a-c would be useful during start-up to initially meter low pressure, low flow to a small number of fuel injectors (not shown) adjacent an igniter (not shown) in the combustion section or augmentor section by using flow through metering orifice 837 and then staging fuel flow thereafter as needed using the sequential orifices 836a-c.

Those skilled in the art will appreciate that the fuel control system described hereinabove will be quite useful to effect sector burning with a combustion section or augmentor section of a gas turbine engine. That is, groups of a limited number of fuel nozzle assemblies or spray bars disposed at specific locations or sectors within these combustion areas can be controlled by the system described. Control of a small number of fuel injection devices adjacent an igniter is just one illustrative example of how sector burning can be effected by the inventive fuel control system. Sector burning can increase temperature uniformity in a particular combustor whether it be in the combustion section 5 or augmentor section 10, can reduce emissions and can enhance start-up performance as well as performance at high altitudes.

And, importantly, the mechanically operated fuel control system of the invention avoids the loss of fuel pressure suffered in prior art control systems because the fuel itself actuates the distribution valve. In the fuel control system of the invention, the fuel staging and distribution valve and/or metering valve is mechanically operated by the synchronizing ring and the fuel pressure drop experienced in prior art systems is now available for use for better fuel atomization at the point of discharge into the combustor for improved starting and operation.

While certain specific and preferred embodiments of the invention have been described in detail hereinabove, those skilled in the art will recognize that various modifications and changes can be made therein within the scope of the appended claims which are intended to include equivalents of such embodiments.

## CLAIMS

1. A fuel control system for a combustor comprising fuel supply means, a plurality of fuel injection means with open discharge orifice means inside the combustor for discharging fuel thereinto, a plurality of valve means outside the combustor in fuel flow relation with the fuel supply means with each valve means including a positive sealing rotary valve and an orifice relative to which the valve is rotated to control fuel flow, conduit means connecting the orifice of each valve means with a respective fuel injection means for discharge of fuel into the combustor through the open discharge orifice means, synchronizing means outside the combustor operatively connected to each valve for rotating the valves relative to the associated

orifice and means for actuating the synchronizing means.

2. A fuel control system for a combustor comprising fuel supply means outside the combustor, a plurality of fuel injection means with open discharge orifice means inside the combustor for discharging fuel thereinto, a plurality of staging valve means outside the combustor in fuel flow relation with the fuel supply mean with each valve means including a positive sealing rotary valve and multiple sequential orifices relative to which the valve is rotated to change fuel flow in stages, conduit means connecting the sequential orifices of each staging valve means with a respective fuel injection means for discharge into the combustor through the open discharge orifice means, synchronizing means outside the combustor operatively connected to each valve for rotating the valves relative to the associated sequential orifices, and means for actuating the synchronizing means.

3. A system according to claim 2 wherein the fuel supply means is an annular fuel manifold around the combustor.

4. A system according to claim 2 wherein the fuel injection means includes a thrust augmentor fuel spray means.

5. A system according to claim 2 wherein the fuel injection means includes a nozzle assembly for the combustion section of a gas turbine engine.

6. A system according to claim 2 wherein each staging valves means includes a spring biased valve disc with a circumferential shut-off and staging groove rotatable relative to the sequential orifices.

7. A system according to any one of claims 2 to 5 wherein each staging valve is pivotally connected to the synchronizing means.

8. A system according to claim 2 wherein the means for actuating the synchronizing means includes a digital electronic control means.

9. A system according to claim 1 wherein a variable area metering orifice is located in sequence with said sequential orifices.

10. A fuel control system for a combustor comprising fuel supply means outside the combustor, a plurality of fuel injection means with open discharge orifice means inside the combustor for discharging fuel thereinto, a plurality of metering valve means outside the combustor in fuel flow relation with the fuel supply means with each valve means including a positive sealing rotary valve and a variable area orifice relative to which the valve is rotated to meter fuel flow, conduit means connecting the variable area orifice of each metering valve means with a respective fuel injection means for discharge into the combustor through said open discharge orifice means, synchronizing means outside the combustor operatively connected to each valve for rotating the valves relative to the associated variable area orifices, and means for actuating the synchronizing means.

11. A system according to claim 10 wherein the fuel supply means is an annular fuel manifold around the combustor.

12. A system according to claim 10 wherein the fuel injection means includes a thrust augmentor fuel spray means.

13. A system according to claim 10 wherein each metering valve includes a spring biased valve disc.

14. A system according to claim 10 wherein each metering valve is pivotally connected to the synchronizing means.

15. A system according to claim 10 wherein each staging valve is pivotally connected to the synchronizing means.

16. A fuel control system for a gas turbine engine comprising casing means defining a combustor, an annular fuel manifold disposed exteriorly around said casing means, a plurality of fuel injection means spaced circum- ferentially in said combustor for discharging fuel into the combustor, a plurality of staging valve means disposed exteriorly and space apart circumferentially around said casing means in fuel flow relation with said fuel manifold and including a positive sealing rotary valve and multiple sequential orifices relative to which the valve is rotated to change fuel flow in stages, conduit means connecting the sequential orifices of each staging valve means with a respective fuel injection means, an annular synchronizing ring disposed around said casing means operatively connected to each valve for rotating same relative to said sequential orifices, and electronically controlled actuator means for moving said synchronizing ring.

17. A system according to claim 15 wherein the fuel injection means comprise spray bars or spray rings.

18. A system according to claim 15 wherein the actuator means comprises a hydraulic piston means and direct drive servovalve means under closed loop digital or analog electronic control.

19. A fuel nozzle assembly comprising a support strut and fuel injection nozzle on the support strut, said strut having fuel inlet means, chamber means receiving fuel from said fuel inlet means, fuel outlet means in fuel flow relation between said chamber means and said nozzle for supplying fuel thereto, and a valve means in said chamber for controlling fuel to said fuel outlet means, said valve means having a rotary valve member, an orifice relative to which said valve member is rotated to control fuel flow to the fuel outlet means and actuated means connected to said valve member and accessible for actuation outside the strut to rotate said valve member relative to said orifice means.

20. An assembly according to claim 19 wherein the actuated means is a shaft extending from the valve member outside the strut for rotation by an external actuator.

21. An assembly according to claim 20 wherein the valve member is a valve disc having a circumferential shut-off and staging groove movable relative to the metering orifices.

22. An assembly according to claim 21 where the valve disc is biased toward said metering orifices by spring means.

23. An assembly according to claim 19 wherein

the orifice means comprises multiple, sequential staging orifices.

24. An assembly according to claim 19 wherein the orifice means comprises a variable area orifice.

25. A fuel control system constructed and arranged substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

26. A fuel nozzle assembly constructed and arranged substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

Printed in the UK for HMSO, D8818935, 9/85, 7102.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.